LARGE-SCALE PRECIPITATION VOLUMES, GRADIENTS, AND DISTRIBUTION

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ABSTRACT

During the past two years, the Quantitative Precipitation Forecast Unit of the National Meteorological Center has collected, as a by-product of its verification program, a large quantity of data relating to observed precipitation amounts. A technique is developed to process these data into precipitation volumes for varying time periods. The technique is simple and provides a fast method of obtaining large-scale precipitation volumes on a day-to-day basis. Similarly, monthly volumes can be easily estimated.

The volumes for a number of larger precipitation storms for periods of one to five days are presented, as well as monthly and annual volumes. An attempt was made to determine a normal isohyetal gradient for individual storms but was successful only with amounts exceeding 3 inches. The volumetric contribution by isohyetal intervals is examined and only in cases of the heaviest storms were the larger amounts found to be important to total volume.

The distribution of heavy precipitation, as portrayed by isopleths of the number of times areas were enclosed by the 1 inch isohyet, is given for each month and for the year. Although the distribution is not too different from that which might be expected, the authors know of no other source for this information.

An addendum permits a comparison of the 1961 and 1962 monthly and annual precipitation volumes. The significant decrease in the 1962 volume emphasizes the deficient rainfall reported over much of the Nation.

1. INTRODUCTION

Since the establishment of the Quantitative Precipitation Forecasting Unit at the National Meteorological Center in September 1960, verification records have been kept as a means of measuring the degree of success of the Unit's quantitative forecasts. These verification records include areal measurements of isohyets obtained in analyzing the 24-hr. observed precipitation charts prepared daily at the National Meteorological Center. The verification method was previously explained [1]. The daily areal measurements of the isohyets are used to obtain precipitation volumes.

Several large-area rainfall statistics for the calendar year 1961 are presented in this study and 1962 data are given in an addendum.

One purpose of this work on storm precipitation volumes is to have information available for research directed toward obtaining a satisfactory quantity control for use in quantitative precipitation forecasting. Also, the Development Branch of the National Meteorological Center is doing research into the incorporation of the latent heat term into baroclinic numerical models. Since precipitation volumes serve as the basis for released latent heat estimates, this information will be of aid to this effort. Precipitation area-depth information for specific storms will be helpful in developing physically realistic numerical methods of predicting precipitaion distribution patterns.

Throughout this report the basic precipitation observational period is for the 24 hr. from 1200 GMT one day to 1200 GMT the following day. The given dates indicate day of measurement. Isohyet and isohyet-interval areas are in square degrees of latitude (3596 n.mi.^{2}), and precipitation volumes are in square-degree inches. For conversion to other units, 1 square-degree inch is equal to 4769 square-statute-mile inches or 0.314 km.^{3} of water. The monthly and annual data are for the contiguous United States and include that portion of Canada south of 49°N., and west of the northern tip of Maine. Data for individual storms are for the region east of the 105th meridian of longitude.

2. PRECIPITATION VOLUMES

ESTIMATION OF STORM VOLUMES

The daily procedure requires isohyetal analyses for standard values of 0.50 in., 1.00 in., 2.00 in., etc. of rainfall for all the contiguous States of the United States and that portion of Canada previously indicated. Figure 1 gives some idea of the density of the reporting network. The network density is sufficient for obtaining the mesoscale patterns of precipitation distribution.

Since no areal records are kept routinely of precipitation amounts under 0.50 in., it was necessary to analyze and measure the daily extent of the 0.01-in. isohyets to complete the statistics or the tables of this report.

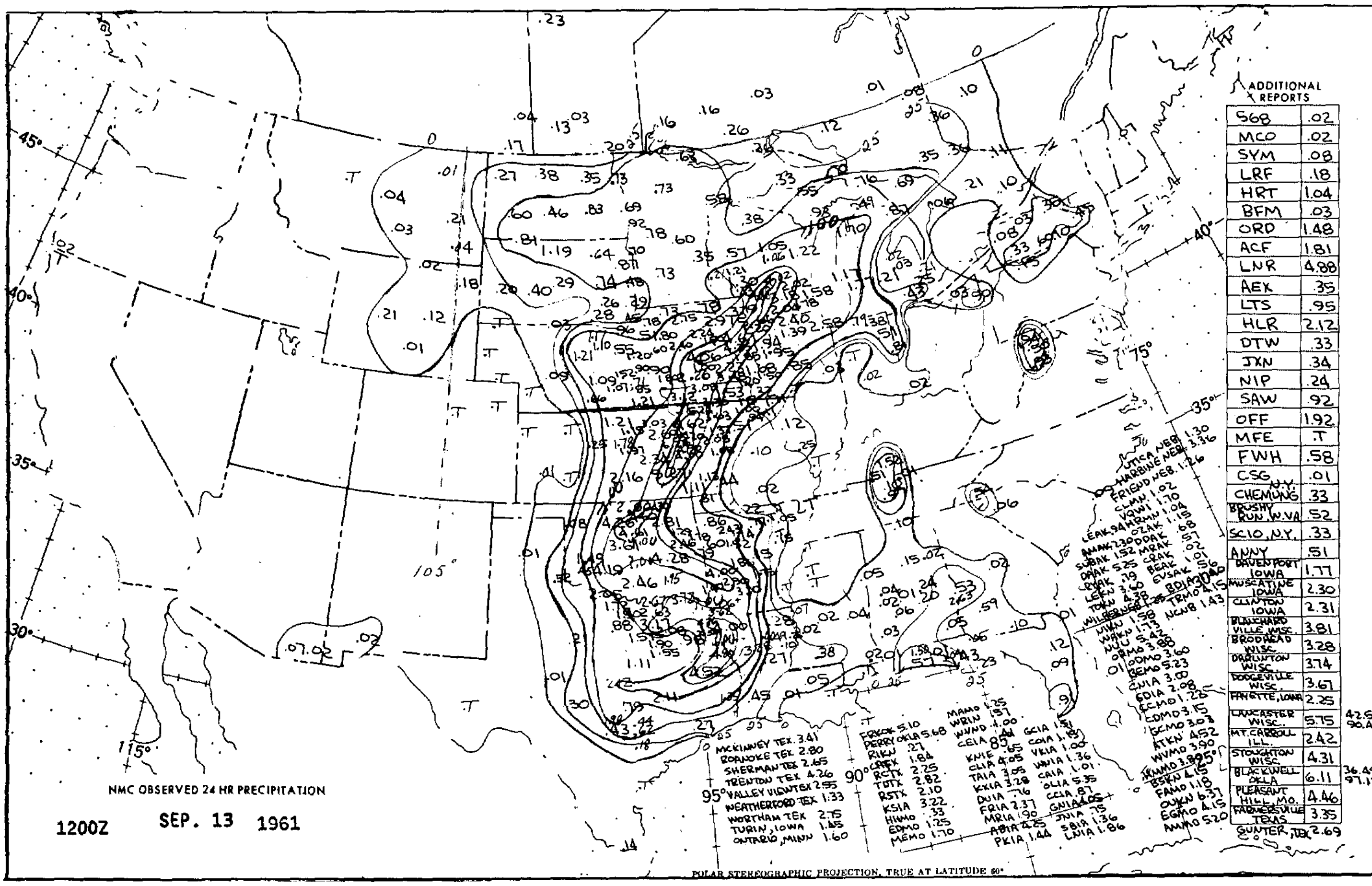


FIGURE 1.—Typical Quantitative Precipitation Forecast Unit analysis of precipitation areas, 1200 GMT, September 13, 1961.

To convert isohyetal areas to volumes, a technique is required for estimating the average precipitation between isohyets. A simple average of the isohyetal values is generally higher than the average of the observations lying between them. The reason for this can be explained by the example of isohyets which are circular and equidistant forming a cone-shaped figure. The average depth between isohyets must be less than the average of the values of the two bounding isohyets since the area with amounts less than the isohyetal average is larger than the area with amounts larger than the isohyetal average. This is true of any isohyetal shape because the smaller valued isohyets always encompass those of larger value.

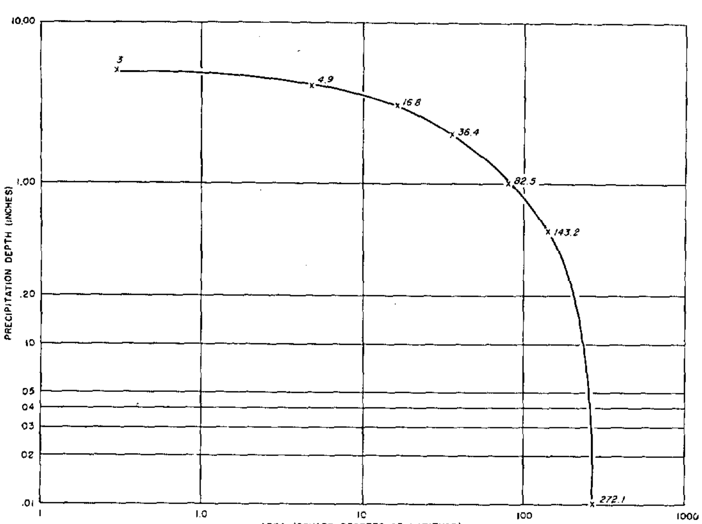


FIGURE 2.—Example of precipitation volume envelope as obtained from measured isohyetal areas. (September 13, 1961)

To correct for this areal effect, smooth curves of precipitation vs. area were plotted for 12 storms, of which an example is shown in figure 2. The depth between the standard isohyetal intervals was obtained by integrating the curve for volume. Inter-isohyetal depths so obtained for 10 of these storms are shown in table 1. The depth factors developed in this way were smoothed, table 2, and utilized in obtaining between-isohyet volumes and total storm volumes.

In any use of precipitation volumes, it should be remembered that there is a variable bias in precipitation measurement which tends to give depths less than physical actuality. Numerous investigations into rain gage measurements, including those by C. Abbe [2], the British Rainfall Organization [3], and Weiss and Wilson [4] have

TABLE 1.—*Precipitation depths (in.) for designated isohyet-intervals as estimated from precipitation volume envelopes for the 10 largest 24-hr. storms of 1961*

Isohyet interval	Feb. 18	June 15	Sept. 12	Sept. 13	Sept. 14	Nov. 3	Nov. 16	Dec. 10	Dec. 12	Dec. 17	Storm average
0.01–0.50	0.18	0.21	0.13	0.18	0.19	0.20	0.21	0.13	0.18	0.20	0.18
0.50–1.00	.71	.71	.70	.71	.73	.73	.73	.79	.71	.71	.72
1.00–2.00	1.39	1.38	1.40	1.42	1.43	1.37	1.33	1.29	1.45	1.49	1.40
2.00–3.00	2.42	2.38	2.46	2.43	2.44	2.31	2.30	2.32	2.32	2.11	2.39
3.00–4.00	3.40	3.38	3.46	3.43	3.42			3.42	3.52		3.43
4.00–5.00	4.56		4.50	4.37	4.50			4.34			4.45
5.00–6.00			5.40					5.35			5.38
6.00–7.00			6.48								6.48
7.00–8.00			7.42								7.42
8.00–9.00			8.41								8.41
9.00–10.00			9.48								9.48
10.00–11.00			10.46								10.46

shown that the measurements are too small because wind decreases the catch of precipitation. General compensation cannot be made for this, since the decrease is mostly a function of the local wind speed at the gage sites. As far as is known, all averages and volumetric computations used in the United States are based on uncompensated reports.

VOLUMES OF OBSERVED STORMS

The volumes for the two largest 24-hr. storms each month of 1961 and for the largest storms of the year for periods ranging to five days were estimated using the values given in table 2. All of these storms occurred east of the 105th meridian. In many cases it was difficult to

TABLE 2.—*Precipitation depths (in.) used in estimating precipitation volumes between designated isohyets*

Isohyet interval	Depth, individual storms	Depth, annual	Isohyet interval	Depth, individual storms	Depth, annual
0.01–0.50	0.18	0.15	5.00–6.00	5.40	5.45
.50–1.00	.70	.70	6.00–7.00	6.40	6.46
1.00–2.00	1.40	1.32	7.00–8.00	7.40	7.41
2.00–3.00	2.40	2.38	8.00–9.00	8.40	8.41
3.00–4.00	3.40	3.36	9.00–10.00	9.40	9.48
4.00–5.00	4.40	4.37	10.00–11.00	10.40	10.46

TABLE 3.—*Isohyetal areas and estimated volumes of the two greatest 24-hr. storms for each month. Interval area and volume are assigned to the lower isohyetal value. Area units are square degrees of latitude; volume units are square-degree inches*

Date 1961		Isohyets 0.01	0.50	1.00	2.00	3.00	4.00	5.00	6.00	Total volume
Jan. 1	Area	227.9	101.7	29.3						
	Interval area	126.2	72.4	29.3						
	Interval volume	22.7	50.7	41.0						114.4
Jan. 8	Area	134.0	34.4	23.2	7.5	3.8	0.6			
	Interval area	99.6	11.2	15.7	3.7	3.2	0.6			
	Interval volume	17.9	7.8	22.0	8.9	10.9	2.6			70.1
Feb. 18	Area	294.7	87.4	35.1	12.3	5.4	2.2	0.8		
	Interval area	207.3	52.3	22.8	6.9	3.2	1.4	0.8		
	Interval volume	37.2	36.6	31.9	16.6	10.9	6.2	4.3		143.8
Feb. 21	Area	168.4	76.6	50.3	19.6	6.6	2.5			
	Interval area	91.8	26.3	30.7	13.0	4.1	2.5			
	Interval volume	16.5	18.4	43.0	31.2	13.9	11.0			134.0
Mar. 6	Area	315.9	92.6	38.2	2.7					
	Interval area	223.3	54.4	35.5	2.7					
	Interval volume	40.2	38.1	49.7	6.5					134.5
Mar. 31	Area	159.0	84.4	44.7	13.5	4.6	1.1	0.3		
	Interval area	74.6	39.7	31.2	8 9	3.5	0.8	0.3		
	Interval volume	13.4	27.8	43.7	21.4	11.9	3.5	1.6		123.3
Apr. 1	Area	208.5	91.3	41.7	12.8	0.6				
	Interval area	117.2	49.6	28.9	12.2	0.6				
	Interval volume	21.1	34.7	40.5	29.3	2.0				127.6
Apr. 12	Area	222.0	88.9	44.1	4.6	0.9	0.3			
	Interval area	133.1	44.8	39.5	3.7	0.6	0.3			
	Interval volume	24.0	31.4	55.3	8.9	2.0	1.3			122.9
May 8	Area	189.8	65.4	37.0	14.7	6.0	0.9			
	Interval area	124.4	28.4	22.3	8.7	5.1	0.9			
	Interval volume	22.4	19.9	31.2	20.9	17.3	4.0			115.7
May 9	Area	215.2	80.4	29.4	2.5					
	Interval area	134.8	51.0	26.9	2.5					
	Interval volume	24.3	35.7	37.7	6.0					103.7
June 15	Area	286.3	115.9	44.4	8.9	0.9	0.3			
	Interval area	170.4	71.5	35.5	8.0	0.6	0.3			
	Interval volume	30.7	50.1	49.7	19.2	2.0	1.3			153.0
June 16	Area	186.6	78.2	42.2	13.4	1.0				
	Interval area	108.4	36.0	28.8	12.4	1.0				
	Interval volume	19.5	25.2	40.3	29.8	3.4				118.2
July 14	Area	285.5	92.7	21.0	1.3	0.4				
	Interval area	192.8	71.7	19.7	0.9	0.4				
	Interval volume	34.7	50.2	27.6	2.2	1.4				116.1
July 21	Area	216.5	90.8	34.3	4.0	0.4				
	Interval area	125.7	56.5	30.3	3.6	0.4				
	Interval volume	22.6	39.6	42.4	8.6	1.4				114.6
Aug. 25	Area	161.6	48.0	20.2	1.1					
	Interval area	113.6	27.8	19.1	1.1					
	Interval volume	20.4	19.5	26.7	2.6					69.2
Aug. 26	Area	176.8	50.4	20.1						
	Interval area	126.4	30.3	20.1						
	Interval volume	22.8	21.2	28.1						72.1
Sept. 13	Area	272.1	143.2	82.5	36.4	16.8	4.9	0.3		
	Interval area	128.9	60.7	46.1	19.6	11.9	4.6	0.3		
	Interval volume	23.2	42.5	64.5	47.0	40.5	20.2	1.6		239.5
Sept. 14	Area	253.5	121.8	66.6	20.8	10.8	3.9	0.7		
	Interval area	131.7	55.2	45.8	10.0	6.9	3.2	0.7		
	Interval volume	23.7	38.6	64.1	24.0	23.5	14.1	3.8		191.8
Oct. 1	Area	177.4	53.2	20.7	2.1	0.6				
	Interval area	124.2	32.5	18.6	1.5	0.6				
	Interval volume	22.4	22.8	26.0	3.6	2.0				76.8
Oct. 11	Area	150.3	72.6	29.3	3.1					
	Interval area	77.7	43.3	26.2	3.1					
	Interval volume	14.0	30.3	36.7	7.4					88.4
Nov. 3	Area	249.3	123.7	59.0	7.4	0.2				
	Interval area	125.6	64.7	51.6	7.2	0.2				
	Interval volume	22.6	45.3	72.2	17.3	0.7				158.1
Nov. 16	Area	246.9	132.2	56.5	5.7	0.6				
	Interval area	114.7	75.7	50.8	5.1	0.6				
	Interval volume	20.6	53.0	71.1	12.2	2.0				158.9
Dec. 10	Area	325.0	79.9	54.8	13.8	2.6	1.0	0.7	0.4	
	Interval area	245.1	25.1	41.0	11.2	1.6	0.3	0.3	0.4	
	Interval volume	44.1	17.6	57.4	26.9	5.4	1.3	1.6	2.6	156.9
Dec. 12	Area	310.9	97.7	46.1	19.7	5.9	3.4			
	Interval area	213.2	51.6	26.4	13.8	2.5	3.4			
	Interval volume	38.4	36.1	37.0	33.1	8.5	15.0			168.1

TABLE 4.—*Isohyetal areas and estimated volumes of the four greatest 48, 72, 96, 120-hr. storms. Interval area and volume are assigned to the lower isohyetal value. Area units are square degrees of latitude; volume units, square-degree inches*

Date 1961		Isohyets												Total volume
		0.01	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
						48-HR. STORMS								
June 15–16	Area	472.9	194.1	86.6	22.3	1.9	0.3							
	Interval area	278.8	107.5	64.3	20.4	1.6	0.3							
	Interval volume	50.2	75.3	90.0	49.0	5.4	1.3							271.2
Sept. 13–14	Area	525.6	265.0	149.1	57.2	27.6	8.8	1.0						
	Interval area	260.6	115.9	91.9	29.6	18.8	7.8	1.0						
	Interval volume	46.9	81.1	128.7	71.0	63.9	34.3	5.4						431.3
Dec. 11–12	Area	612.1	186.7	78.9	25.3	8.2	3.4							
	Interval area	425.4	107.8	53.6	17.1	4.8	3.4							
	Interval volume	76.6	75.5	75.0	41.0	16.3	15.0							299.4
Dec. 17–18	Area	543.9	191.3	85.4	23.2	4.3								
	Interval area	352.6	105.9	62.2	18.9	4.3								
	Interval volume	63.5	74.1	87.1	45.4	14.6								284.7
						72-HR. STORMS								
June 14–16	Area	741.7	276.8	111.9	23.1	1.9	0.3							
	Interval area	464.9	164.9	88.8	21.2	1.6	0.3							
	Interval volume	83.7	115.4	124.3	50.9	5.4	1.3							381.0
Sept. 12–14	Area	768.5	326.5	182.9	71.4	36.6	15.1	5.2	2.7	2.0	1.4	0.8	0.3	
	Interval area	442.0	143.6	111.5	34.8	21.5	9.9	2.5	0.7	0.6	0.6	0.5	0.3	
	Interval volume	79.6	100.5	156.1	83.5	73.1	43.6	13.5	4.5	4.4	5.0	4.7	3.1	571.6
Dec. 10–12	Area	916.7	266.2	133.3	38.7	10.4	4.0	0.3						
	Interval area	650.5	132.9	94.6	28.3	6.4	3.7	0.3						
	Interval volume	117.1	93.0	132.4	67.9	21.8	16.3	1.6						450.1
Dec. 16–18	Area	687.7	217.0	93.6	23.2	4.3								
	Interval area	470.7	123.4	70.4	18.9	4.3								
	Interval volume	84.7	86.4	98.6	45.4	14.6								329.7
						96-HR. STORMS								
May 6–9	Area	794.1	274.9	118.1	27.4	8.0	1.3							
	Interval area	519.2	156.8	90.7	19.4	6.7	1.3							
	Interval volume	93.5	109.8	127.0	46.6	22.8	5.7							405.4
June 14–17	Area	927.7	311.5	136.1	30.5	3.9	0.3							
	Interval area	616.2	175.4	105.6	26.6	3.6	0.3							
	Interval volume	110.9	122.8	147.8	63.8	12.2	1.3							458.8
Sept. 12–15	Area	972.1	388.0	195.7	73.0	36.6	15.1	5.2	2.7	2.0	1.4	0.8	0.3	
	Interval area	584.1	192.3	122.7	36.4	21.5	9.9	2.5	0.7	0.6	0.6	0.5	0.3	
	Interval volume	105.1	134.6	171.8	87.4	73.1	43.6	13.5	4.5	4.4	5.0	4.7	3.1	650.8
Dec. 10–13	Area	1149.6	327.5	165.5	48.3	11.1	4.4	0.7	0.4					
	Interval area	822.1	162.0	117.2	37.2	6.7	3.7	0.3	0.4					
	Interval volume	148.0	113.4	164.1	89.3	22.8	16.3	1.6	2.6					558.1
						120-HR. STORMS								
Feb. 18–22	Area	1041.9	339.4	163.6	53.3	18.4	8.0	2.6	0.5					
	Interval area	702.5	175.8	110.3	34.9	10.4	5.4	2.1	0.5					
	Interval volume	126.5	123.1	154.4	83.8	35.4	23.8	11.3	3.2					561.5
May 5–9	Area	930.6	335.6	146.1	33.1	8.3	1.3							
	Interval area	595.0	189.5	113.0	24.8	7.0	1.3							
	Interval volume	107.1	132.7	158.2	59.5	23.8	5.7							487.0
Sept. 11–15	Area	1132.7	434.7	209.8	74.6	36.8	15.1	5.2	2.7	2.0	1.4	0.8	0.3	
	Interval area	698.0	224.9	135.2	37.8	21.7	9.9	2.5	0.7	0.6	0.6	0.5	0.3	
	Interval volume	125.6	157.4	189.3	90.7	73.8	43.6	13.5	4.5	4.4	5.0	4.7	3.1	715.6
Dec. 9–13	Area	1438.3	387.1	193.5	49.5	11.1	4.4	0.7	0.4					
	Interval area	1051.2	193.6	144.0	38.4	6.7	3.7	0.3	0.4					
	Interval volume	189.2	135.5	201.6	92.2	22.8	16.3	1.6	2.6					661.8

determine the precipitation boundaries of individual storm systems, particularly during the summer months. However, in the cases of large storms, such as the ones dealt with in this article, one synoptic system usually was responsible for most of the observed precipitation.

The two greatest 24-hr. storm volumes for each month are presented in table 3. Also listed are the areas enclosed within the individual isohyets, the areas between the isohyets (the area being accredited to the lower isohyetal boundary), and the volumetric contribution to the total storm volume by the amounts between isohyets. Table 4 gives the same information for the four greatest storms in 1961 for two-, three-, four-, and five-day periods. Total isohyetal areas, and indirectly total volumes, for storm periods longer than one day were obtained by adding the 24-hr. areas, and not from isohyetal analysis of total precipitation depth occurring during the longer period.

No description of the individual meteorological systems

TABLE 5.—*Total and average isohyet-interval areas (square degrees of latitude) for 26 large-volume storms. Interval area is assigned to the lower isohyet value*

	Isohyet						
	0.50	1.00	2.00	3.00	4.00	5.00	6.00
Total interval area	1224.4	794.9	171.1	50.4	20.4	3.9	0.4
Number of cases	26	26	24	20	12	6	1
Average interval area	47.09	30.57	7.15	2.52	1.70	0.65	0.40

is included in this paper, but some comment on the storm of September 11–15 is relevant since it produced the greatest volume during 1961 for all duration categories. This storm ranks high in the all-time storm records of large-scale production of heavy precipitation. This major event initially was associated with hurricane Carla. As Carla moved inland across Texas, very heavy rain fell over Texas and Louisiana; Bay City, Texas reported a storm total of 17.62 in. Heavy rain continued on the succeeding few days over most of the Mississippi Valley as Carla became associated with a baroclinic low pressure development over the Central Plains States which moved northeastward across the Great Lakes Region.

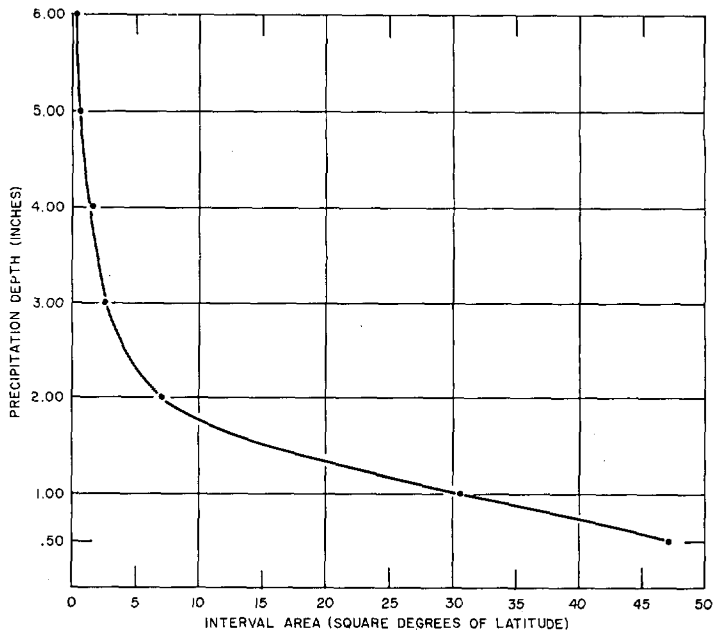


FIGURE 3.—Isohyet-interval areal relationship curve for 26 large-volume storms. Interval area is assigned to the lower isohyetal value.

STORM ISOHYET-INTERVAL AREAL RELATIONSHIPS

Total areas between standard isohyets for 26 cases of important 24-hr. storms during the year are shown in table 5. These total areal values are for the two largest volume storms each month, and in addition those of September 12 and December 17 which were not included in the monthly grouping, but were among the major ten storms of the year. Table 5 also gives the average area for each of the standard isohyet intervals obtained by dividing the total for each interval by the number of occurrences in each interval. A plot of these averages (fig. 3) indicates a curve of general logarithmic character. The tendency might be to use this curve in forecasting areal extent of precipitation amounts. However, an examination of individual cases (table 3) shows great variability in the rate of decrease in areal extent for intervals up to 3 in. For amounts over 3 in. there is more evidence of uniformity similar to the average curve in which succeeding interval areas decrease by approximately one-half. This relation may be of some aid in forecasting the isohyetal gradients of excessive precipitation.

MONTHLY AND ANNUAL VOLUMES

The precipitation volumes for July, December, and for the year were calculated from volumetric envelopes similar to figure 2. The volumetric envelopes were constructed from the summation of 24-hr. isohyetal areas for the periods. The resulting between-isohyet averages from the annual curve are listed in table 2. It was noted that the between-isohyet averages above 1.00 in. were quite similar for the three periods. Monthly volumes are shown in table 6. These were calculated from the volumetric envelopes for depths up to 1.00 in. Above 1.00 in., areas were converted to volumes by use of the annual between-isohyetal values in table 2.

The annual precipitation volume was converted into an average depth over the total area involved and compared with the last available climatic average rainfall for the United States for the 63-yr. period from 1893 through 1955. The 1961 computed average was 28.81 in. as compared to the climatic average of 29.03. The average annual precipitation of that portion of Canada included in this study is near 30 in., and therefore, has little effect in invalidating this comparison. It should be pointed out that reports from mountainous areas are sparse as compared to other areas. This paucity of data probably leads to a moderate degree of underestimation of precipitation volume in mountainous regions, both in 1961 and to some extent in the climatic normal, and consequently, a slight underestimation of actual total volume for the United States as a whole.

CONTRIBUTION OF ISOHYET-INTERVAL VOLUME TO TOTAL VOLUME

The contribution to the total precipitation volume by the amounts between isohyets varied from storm to storm (see tables 3 and 4). In all cases, the amounts less than one-half inch contributed an important portion of the total volume. In the monthly and annual totals, this contribution was greater than for any other isohyet-interval. In the case of the individual heavy storms, the 1.00- to 2.00-in. isohyet-interval contributed more toward

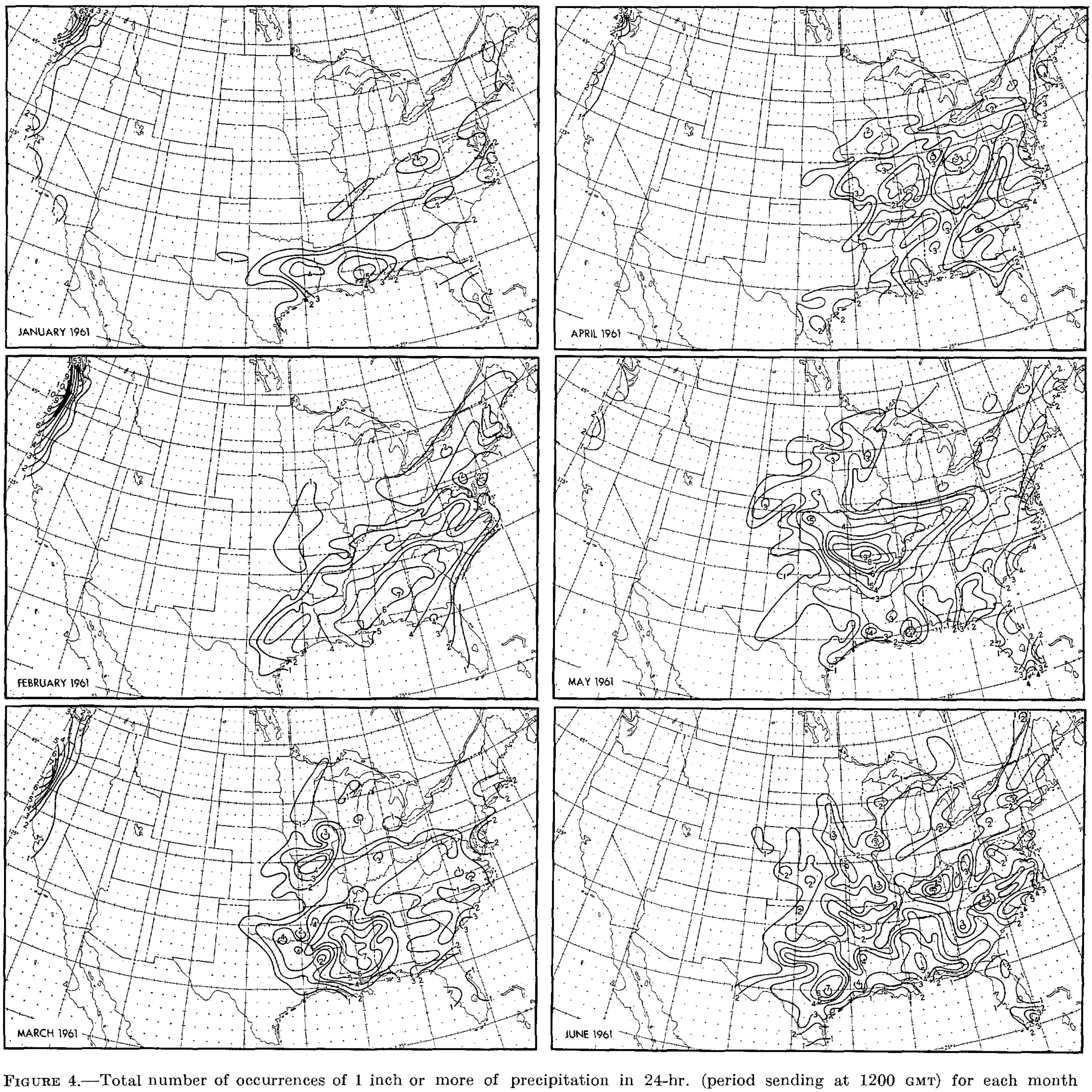


FIGURE 4.—Total number of occurrences of 1 inch or more of precipitation in 24-hr. (period sending at 1200 GMT) for each month of 1961 and for the year 1961.

total volume than any other interval considered. If the smaller valued isohyet classifications are combined so as to make the separation of all isohyets equal to 1 inch, then in most 24-hr. storm cases, and in all but one of the longer-period storm cases, precipitation amounts of less than 1 inch contributed the largest proportion of the total volume. The 2.00- to 3.00-in. interval contributed an important proportion of the total volume in individual heavy storms, but was less important when considered over monthly periods. Only in the cases of the heaviest storms did amounts of 3 to 4 in. or more, have a significant influence on the total storm volume.

3. DISTRIBUTION OF HEAVY PRECIPITATION

The 1-in. isohyets, as analyzed from the 24-hr. observed daily precipitation charts, were compiled into monthly frequency isopleths of the occurrence of 1 or more inches of precipitation (fig. 4). The daily 1-inch isohyets were

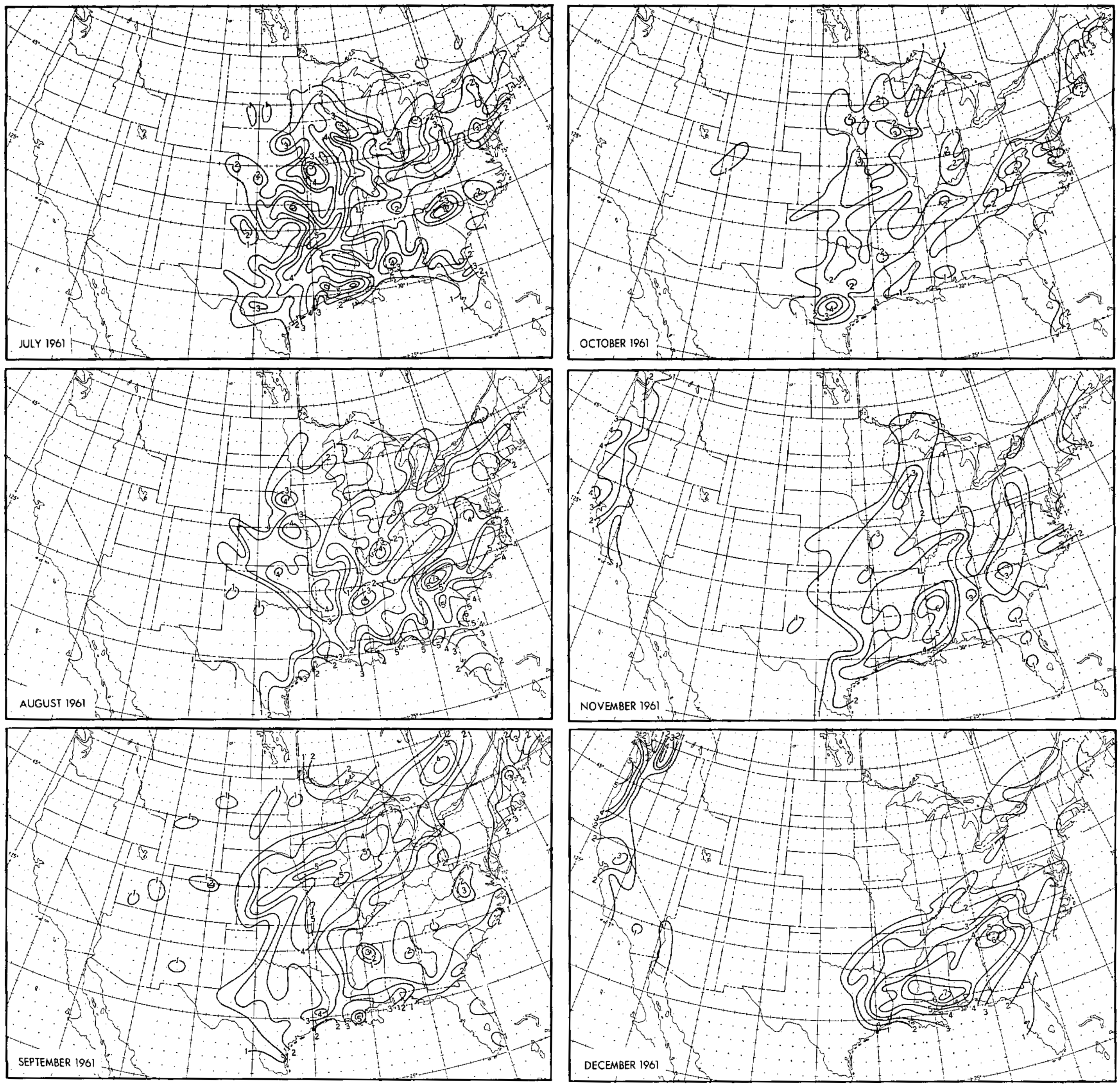
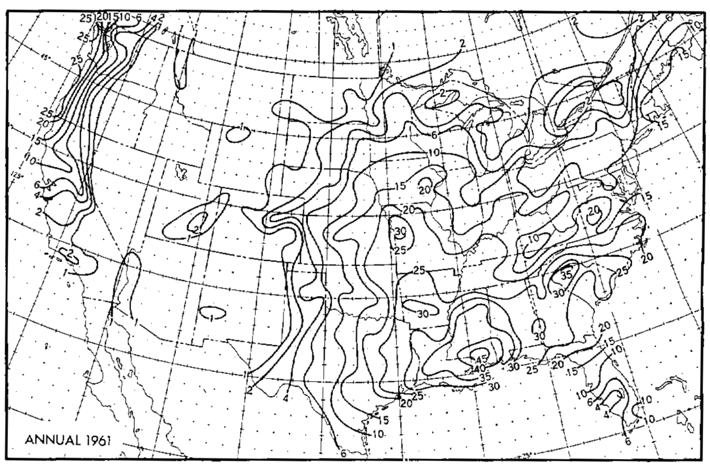


Figure 4.—Concluded.



added graphically for each of the cooler six months—November through April. Since the original daily isohyets were of a reasonably uniform nature during that period of the year, the graphical addition resulted in relatively smooth total isopleths. During the warmer half of the year, the daily isohyetal areas became smaller and much more irregular, which necessitated the totaling of individual point occurrences. Although for this period a larger number of points was used than available from the regular

TABLE 6.—*Monthly and annual isohyetal areas and volumes. Isohyet-interval volumes are estimated (table 2) except that those for precipitation depths up to 1 inch are actual values from the monthly volumetric envelopes. Interval area and volume are assigned to the lower isohyetal value. Area units are square degrees of latitude: volume units, square-degree inches*

Month 1961		Isohyet												Total volume
		0.01	0.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
January	Area	3,557.4	521.5	147.0	11.5	3.8	0.6							
	Interval area	3,035.9	374.5	135.5	7.7	3.2	0.6							
	Interval volume	371.8	253.4	178.9	18.3	10.8	2.6							835.8
February	Area	5,009.2	980.1	370.4	73.0	25.8	9.5	2.6	0.5					
	Interval area	4,029.1	609.7	297.4	47.2	16.3	6.9	2.1	0.5					
	Interval volume	537.2	431.4	392.6	112.3	54.8	30.2	11.4	3.2					1,573.1
March	Area	6,989.8	1,178.1	350.3	48.1	11.7	2.2	0.3						
	Interval area	5,811.7	827.8	302.2	36.4	9.5	1.9	0.3						
	Interval volume	929.5	580.5	398.9	86.6	31.9	8.3	1.6						2,037.3
April	Area	6,166.0	990.3	299.2	28.3	4.6	1.9	0.2						
	Interval area	5,175.7	691.1	270.9	23.7	2.7	1.7	0.2						
	Interval volume	756.5	483.6	357.6	56.4	9.1	7.4	1.1						1,671.7
May	Area	5,966.1	1,191.9	386.2	52.7	11.0	2.2	0.3						
	Interval area	4,774.2	805.7	333.5	41.7	8.8	1.9	0.3						
	Interval volume	738.1	557.4	440.2	99.2	29.6	8.3	1.6						1,874.4
June	Area	5,491.9	1,345.3	499.0	86.0	17.5	5.4	1.5	0.6	0.4				
	Interval area	4,146.6	846.3	413.0	68.5	12.1	3.9	0.9	0.2	0.4				
	Interval volume	667.2	593.3	545.2	163.0	40.7	17.0	4.9	1.3	3.0				2,035.6
July	Area	6,077.2	1,401.3	422.0	55.2	13.1	4.1	1.4	0.6	0.2				
	Interval area	4,675.9	979.3	366.8	42.1	9.0	2.7	0.8	0.4	0.2				
	Interval volume	781.8	672.0	484.2	100.2	30.2	11.8	4.4	2.6	1.5				2,088.7
August	Area	5,236.4	1,006.5	323.6	26.7	3.9	0.9	0.2						
	Interval area	4,229.9	682.9	296.9	22.8	3.0	0.7	0.2						
	Interval volume	619.5	485.6	391.9	54.3	10.1	3.1	1.1						1,565.6
September	Area	5,243.7	1,097.0	394.9	104.4	44.8	17.6	5.6	2.7	2.0	1.4	0.8	0.3	
	Interval area	4,146.7	702.1	290.5	59.6	27.2	12.0	2.9	0.7	0.6	0.6	0.5	0.3	
	Interval volume	632.3	485.3	383.5	141.8	91.4	52.4	15.8	4.5	4.4	5.0	4.6	3.2	1,824.2
October	Area	4,250.5	632.6	167.4	18.5	4.8	1.6	1.0	0.4					
	Interval area	3,617.9	465.2	148.9	13.7	3.2	0.6	0.6	0.4					
	Interval volume	479.1	327.6	196.5	32.6	10.8	2.6	3.3	2.6					1,055.1
November	Area	5,426.1	959.9	352.2	61.4	15.6	4.9	0.9						
	Interval area	4,466.2	607.7	290.8	45.8	10.7	4.0	0.9						
	Interval volume	636.2	426.9	383.9	109.0	36.0	17.5	4.9						1,614.4
December	Area	5,944.8	988.4	380.6	76.1	15.4	4.4	0.7	0.4					
	Interval area	4,956.4	607.8	304.5	60.7	11.0	3.7	0.3	0.4					
	Interval volume	616.4	428.6	401.9	144.5	37.0	16.2	1.6	2.6					1,648.8
Year	Area	65,359.1	12,292.9	4,092.8	641.9	172.0	55.3	14.7	5.2	2.6	1.4	0.8	0.3	
	Interval area	53,066.2	8,200.1	3,450.9	469.9	116.7	40.6	9.5	2.6	1.2	0.6	0.5	0.3	
	Interval volume	7,765.6	5,725.6	4,555.2	1,118.4	392.1	177.4	51.8	16.8	8.9	5.0	4.6	3.2	19,824.7

synoptic reporting network, the analyses still do not reflect the entire irregularity of the frequency pattern.

These monthly charts indicate the seasonably preferred regions of heavy precipitation in 1961. The heavy amounts, except for the west coast, occurred well south during the winter months with greatest frequency south of 35° N. As the weather warmed, the frequency of heavy precipitation shifted northward, until by May, the center of greatest frequency was just north of 35° N. However, even in May, the heavy amounts were infrequent north of 40° N. The patterns during the summer mouths indicated a moderately uniform frequency of heavy precipitation over that area of the United States east of the 105th meridian and south of 45° N., but with a slight tendency for the least frequent occurrence over the Great Lakes Region.

The frequency pattern for September showed the influence of the unusually heavy precipitation which accompanied hurricane Carla in its northward and northeastward path through the United States. The other autumn months showed a gradual retreat of heavy amounts toward the Gulf of Mexico.

The seasonal change in the occurrence of heavy precipitation along the west coast during 1961 was quite similar to the normal pattern. Not one case of heavy precipitation occurred during the four warm months of June through September. The three winter months of December through February provided the greatest number of cases of heavy precipitation with the highest frequency during February.

The frequency of heavy precipitation amounts for the year as a whole (last map in fig. 4) was obtained by totaling the number of times that 1 inch or more of precipitation was observed at individual points. In general the annual analysis indicates the most frequent occurrence of heavy precipitation amounts was in an area latitudinally over the Southern States, and, to a lesser degree, longitudinally through the Mississippi Valley.

4. SUMMARY

Some insight has been obtained into the volume and distribution of daily rainfall over the central and eastern United States by analyzing principal storms during 1961 from readily available data. Average between-isohyet

TABLE 7.—*Comparison of monthly and annual isohyetal areas, and annual estimated volumes for 1961 and 1962. Interval area and volume are assigned to the lower isohyetal value. Area units are square degrees of latitude; volume units, square-degree inches*

	Isohyet																Totals	
	0.01		0.50		1.00		2.00		3.00		4.00		5.00		Over 6.00			
	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962
January area	3,557.4	----	521.5	822.4	147.0	274.7	11.5	31.6	3.8	20.3	0.6	0.9	----	0.3	----	----	----	----
February area	5,009.2	----	980.1	781.8	370.4	243.8	73.0	29.5	25.8	6.4	9.5	0.7	0.5	0.1	0.5	----	----	----
March area	6,989.8	----	1,178.1	664.7	350.3	210.6	48.1	12.1	11.7	1.2	2.2	----	0.3	----	----	----	----	----
April area	6,166.0	----	990.3	768.1	299.2	287.8	28.3	46.8	4.6	14.3	1.9	4.9	0.2	1.1	----	0.3	----	----
May area	5,966.1	----	1,191.9	1,013.9	386.2	304.6	52.7	41.7	11.0	6.3	2.2	0.8	0.3	----	----	----	----	----
June area	5,491.9	----	1,345.3	1,579.6	499.0	501.5	86.0	43.0	17.5	5.6	1.5	1.0	0.6	0.7	0.6	0.3	----	----
July area	6,077.2	----	1,401.3	1,245.1	422.0	370.5	55.2	51.1	13.1	10.5	1.4	2.8	0.6	0.7	0.6	0.4	----	----
August area	5,236.4	----	1,006.5	818.7	323.6	268.2	26.7	39.6	3.9	9.3	0.9	2.0	0.2	1.2	----	0.8	----	----
September area	5,243.7	----	1,097.0	1,220.0	394.9	410.2	104.4	52.4	44.8	7.3	17.6	1.8	5.6	0.9	2.7	0.5	----	----
October area	4,250.5	----	632.6	904.1	167.4	298.7	18.5	58.0	4.8	16.7	1.6	5.3	1.0	1.1	0.4	0.3	----	----
November area	5,426.1	----	959.9	718.0	352.2	295.6	61.4	49.0	15.6	10.6	4.9	2.3	0.9	0.1	----	----	----	----
December area	5,944.8	----	988.4	609.1	380.6	175.0	76.1	19.4	15.4	2.5	4.4	0.3	0.7	----	0.4	----	----	----
Total area	65,359.1	----	12,292.9	11,145.5	4,092.8	3,641.2	641.9	474.2	172.0	111.0	55.3	22.8	14.7	6.2	5.2	2.6	----	----
Total interval area	53,066.2	*48,564.1	8,200.1	7,504.3	3,450.9	3,167.0	469.9	363.2	116.7	88.2	40.6	16.6	9.5	3.0	5.2	2.6	----	----
Total interval volume	7,765.6	7,090.4	5,725.6	5,238.0	4,555.2	4,212.2	1,118.4	864.4	392.1	296.3	177.4	72.5	51.8	16.4	38.5	18.3	19,824.7	17,808.5
1962 percent of 1961 volume	----	91	----	91	----	92	----	77	----	76	----	41	----	32	----	48	----	90

*Obtained by using the 1961 ratio of the area within the 0.01-in. isohyet to that within the 0.50-in. isohyet.

depths were determined which are satisfactory for quickly obtaining reliable estimates of volume of large-scale precipitation on both a storm and monthly basis.

It was found that 24-hr. precipitation depths of less than 0.50 in. contributed more to monthly precipitation volume than any of the standard isohyet intervals. In most of the large 24-hr. storms, the contribution toward total precipitation volume from depths less than 1 inch was more than the contribution of any one of the other isohyetal intervals.

For depths less than 3 inches, the year's data showed no evidence of a normal spectrum in precipitation depth gradients which would be of value in forecasting precipitation areal-depth relations for individual storms. For depths over 3 inches, the relationship of areas between isohyets had more semblance of uniformity, decreasing by approximately one-half from the lower interval to the next higher interval.

The number of occurrences of 1 inch or more of precipitation (fig. 4) followed in general a pattern that would be expected from precipitation normals and geographical location. The change in character of the patterns from winter to summer, while not unexpected, emphasizes the importance of the meso-scale character of summer precipitation. One year of data is too limited to make valid comments regarding unusual climatological occurrences of 1 inch or more of precipitation.

Those wishing to make further investigations, perhaps more suitable to their special areas of interest, are welcome to use the original data and computations available at the National Meteorological Center.

ADDENDUM

REMARKS ABOUT 1962 OBSERVED PRECIPITATION

Precipitation data for the year 1962 differed considerably from those of 1961. The authors believe that these data are of sufficient climatical and statistical interest to justify including a brief summary of this new information.

Table 7 gives the total areas within the standard isohyetal values measured during routine verification for each month of 1962. These, and isohyet-interval areas, are compared with those for the corresponding months in 1961. The overall totals for the period are in a form similar to table 6. An estimate for the 1962 0.01 to 0.50-in. interval area was obtained by using the 1961 ratio of the measured area within the 0.01-in. isohyet to that within the 0.50-in. isohyet. The total volumes were arrived at by using the annual between-isohyet depths determined from 1961 data (table 2). The ratio of the 1962 volumes to those of 1961 point to a marked decrease in precipitation over the United States during 1962 with the comparative deficiency of total volume amounting to 10 percent.

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